# Behavioral Ecology of Narwhals in a Changing Arctic

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## LONG-TERM GOALS

Our primary goal is to understand baseline narwhal (*Monodon monoceros*) behavioral ecology in the pack ice of Baffin Bay. We will collect data on the species' acoustic, movement, and diving ecology in the offshore pack ice of Baffin Bay over a 4 year long research program with three ecological focus areas (acoustic ecology, sea ice ecology, and foraging ecology). Our longitudinal and cross-population analyses will use a suite of ecological modeling approaches over a >2 decade period that encompass a period of sea ice decline and increased anthropogenic activities in West Greenland (1993-present).

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## OBJECTIVES

Our objectives are to answer the following science questions:

1. Acoustic ecology: What are baseline characteristics of the acoustic repertoire of narwhals in the offshore Baffin Bay pack ice (depth-specific high frequency calls, echolocation clicks, and buzzes during foraging dives)? What is the ecophysiological and communicative function of various click types of narwhals in this high-latitude offshore ice covered habitat? How might acoustic communication and foraging ecology be impacted by increasing anthropogenic activities in Baffin Bay (increasing shipping, future transit through the NW Passage, seismic exploration, increasing tourism)?

2. Sea ice habitat selection: How are narwhals' movements in Baffin Bay related to sea ice concentration, distance to the sea ice edge, location of glacial outlets, and the timing of sea ice break-up (as measured by the date when sea ice concentration drops below some threshold)? How have these relationships changed over the past two decades of sea ice loss? Are there population-level differences in sea ice habitat selection?

3. Foraging ecology: Do the winter home ranges of narwhals overlap with high densities of Greenland halibut and are there habitat parameters that quantitatively describe the overlap of this predator and its prey? What is the potential predation impact on the offshore Greenland halibut stock as measured by bioenergetic models using updated narwhal abundance estimates, recent fisheries survey data, and knowledge of populations hot spots?

4. Predation: What are the spatial and temporal trends in the occurrence of killer whales in West Greenland? Given the loss of annual sea ice and purported increase in killer whales in the Canadian Arctic, do killer whale catch and observation data from West Greenland follow this trend and have narwhals been exposed to increasing risk of predation?

## APPROACH

*Pack ice field work*

We designed and built an acoustic recording station set up at leads in pack ice within high-density offshore narwhal wintering grounds. This station records depth-specific high frequency calls, echolocation clicks, and buzzes on narwhal foraging dives. We take two approaches to collecting acoustic data from narwhals. First, we are deploying a 15Hz-480kHz Reson hydrophone with pre-amplifier and recording using a National Instruments sound card with a sample rate of 500 kHz. Recent studies using wide-band acoustic sampling in the Northeast Atlantic have documented killer whales (*Orcinus orca*), the largest delphinid, produce whistles with the highest fundamental frequencies ever reported (Samarra et al. In Press). These ultrasonic whistles may also occur in medium sized odontocetes (i.e. narwhals) but has never been studied. The use of this first approach will ensure that the sampling scheme used to collect baseline data on narwhal acoustics in the pack ice is not inherently constrained by *a priori* sampling decisions (where insufficient sampling frequency results in portions of whistles being missed). Second, we utlilize a custom made 16 channel vertical array (with a laptop and pre-amplifier inside an insulated aluminium box) as a stand-alone system recording between the surface and 25 m.

Field work in the pack ice is in spring 2012 and 2013. All personnel and equipment will be deployed and retrieved from the ice using an Air Greenland helicopter (AS350). The helicopter will be used for spotting groups of narwhals and identifying ideal locations for deploying hydrophones. We will also attempt to instrument narwhals with satellite-linked time-depth recorders (SPLASH tags, Wildlife Computers) from leads in the ice. SPLASH tags collect information on animal location via the Argos system in addition to information on diving behavior.

*Analysis and habitat modeling*

We are using an extensive data analysis of over 18 years of satellite tracking and dive data (1993-2009) from five different narwhal subpopulations (Dietz and Heide-Jørgensen 1995, Dietz et al. 2001, Heide-Jørgensen et al. 2002, Heide-Jørgensen et al. 2003, Dietz et al. 2008). The satellite tracking database includes tracking data from n=79 individual narwhals tagged in Melville Bay (West Greenland), Somerset Island (Canada), Eclipse Sound (Canada), and Admiralty Inlet (Canada), and Uummannaq (West Greenland).We will use the narwhal satellite tracking data to identify individual trajectories, focal areas, and population-level home ranges. We will examine speed, dispersal, and movements under different ice regimes and quantify fine scale winter habitat selection/sea ice characteristics within focal areas by extracting a suite of habitat variables and remotely-sensed data on sea ice conditions. Sea ice concentration data will be used to construct resource selection functions (RSFs), to compute long-term trends in sea ice parameters in specific regions of Baffin Bay identified as important to narwhals, and to compute sea ice parameters along the trajectories followed by narwhals. Satellite passive microwave data from SMMR and SSM/I (1979-present) (25-km pixel size) will be the primary data source for investigating ice trends. AMSR-E data will be used to compute specific parameters in the post-2002 period at a higher resolution (6.25 km pixel size). We will also use AMSR-derived daily sea ice velocity fields in Baffin Bay (supplied by Dr. Ron Kwok at the Jet Propulsion Laboratory) and SSM/I-derived sea ice velocity fields (from NSIDC in Boulder) to characterize the sea ice velocity and its variability. Finally, we will use information on the ice front location, discharge rates and advancement or recession trends in glacial ice drainage sites along the coast of West Greenland (Moon and Joughin 2008) where narwhals migrate to quantify preference or avoidance of glacial ice habitat.

We will compile all available data on killer whale occurrence, dedicated and opportunistic sightings, and harvest records in West Greenland and Baffin Bay since 1970s and look at trends in the occurrence of narwhal predators, as well as spatial and temporal overlap based on the spatial models of area use. These records are kept by the Hunting Department of the Government of Greenland and for each catch record of killer whales details are recorded by hunters (submitted in catch reporting annually) and are available to our study through our collaboration with the Greenland Institute of Natural Resources.

## WORK COMPLETED

**2013 Field work.** We conducted our field season in March 2013. Average air temperatures were -21C and sea ice was >98% concentration. There was a warm period just before the field season started and the sea ice had been blown offshore, which required us to fly approximately 50 nmi over open water to reach the ice. We were based out of Niaqornat Greenland between March 21 and April 1. We flew a total of 36 hours and 54minutes and recorded over 41 minutes of narwhal data at 13 stations using the Reson hydrophone/National Instruments system (with both marine battery) and the 16 channel vertical array. We recorded between 50 and 250 m depths.

**Analysis work.** We have published two papers in 2013 and continue analysis on the acoustic data. One paper discusses the metapopulation structure of narwhals based on satellite telemetry from several sub-populatoins and genetics, and the second paper is a review and simnulation model of the impacts of climate change on migratory species, such as narwhals. We are working on a manuscript relating winter movements in Baffin Bay to fluctuations in sea ice cover which is as well as a manuscrip summarixing the ultra-high frequency clicks of narwhals. Both are expected to be submitted in 2014.

**RESULTS**

Our primary accomplishment for the second year of the project was a successful study in the pack ice of Baffin Bay in 2013. We continue to collect data that show narwhals make very high frequency clicks, up to 200 kHz, and have prepared a draft manuscript summarizing the data. These frequencies not been recorded before from narwhals. We also recorded foraging buzzes concurrent with behavioral observations of foraging diving and are in the process of examining collected data. The study demonstrated that it is necessary to be close to pods of narwhals (<1 km) to make high quality recordings. This is complicated considering the moving sea ice landscape, skittish whale behavior, restricted landing sites on the ice with a 2,200 kg helicopter, and unstable small weather systems (e.g. fog and snow) moving in and out. We were able to get good access to pods of narwhals several times during our work. The Reson hydrophone and National Instruments recording system functioned very well in the cold, an aluminum box held a rugged laptop and 4 heating elements (with insulation). In 2013 we introduced a 16 channel vertical array that was customized for the cold. This system recorded narwhal clicks and click intervals on all 16 channels and produced excellent data. We are currently processing the data from this system. We also opportunistically recorded beluga whales on 2 occasions in 2013 so that we can do an inter-species comparison of clicks.

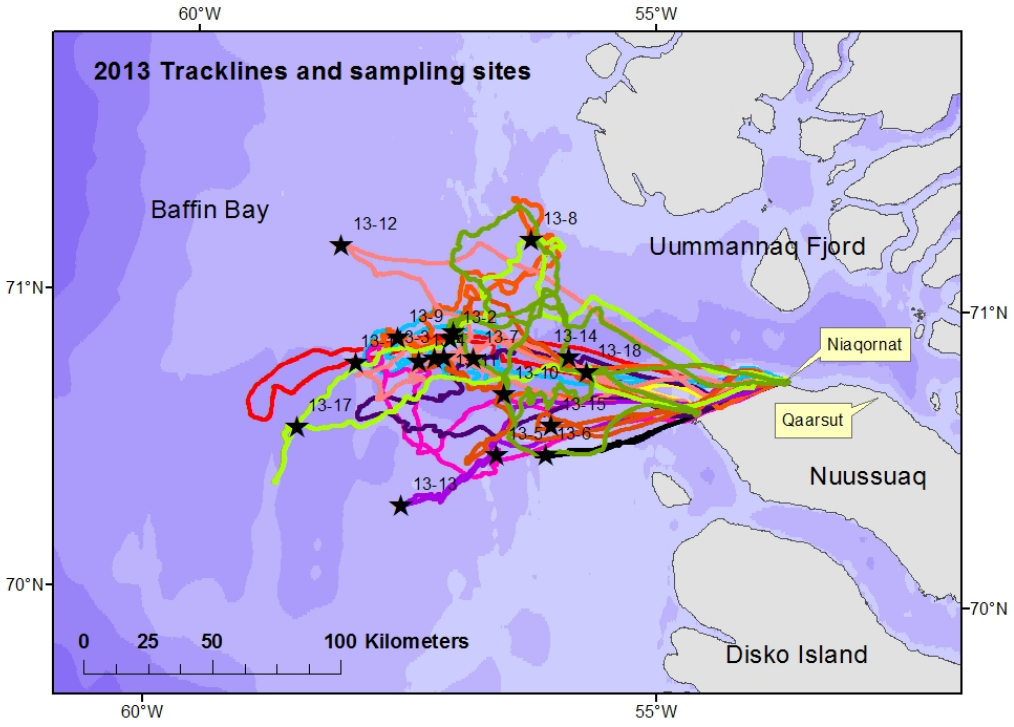


***Figure 1. Map of helicopter tracklines and sampling sites in the offshore Baffin Bay pack ice during field work in March 2013. Colors represent individual daily flight paths and stars show each sampling site where acoustic recordings were collected.***

## IMPACT/APPLICATIONS

**1. New baseline information on the ecology of narwhals in the pack ice.** This study will provide the first critical baseline data on acoustic foraging ecology of narwhals in an area rapidly being altered by increases in shipping, seismic exploration, and sea ice loss. We anticipate our results will be of broad interest to managers for predicting impacts of anthropogenic activities on this vulnerable species.

Potential future impact for Science and/or Systems Applications

**1. New techniques for ecological studies of whales using telemetry.** Our study develops technical and methodological advances for whale tagging in the Arctic. Design and deployment of satellite transmitters for whales will be refined based on field efforts during this project to improve attachment.

## RELATED PROJECTS

None.

**PUBLICATIONS**

Heide-Jørgensen, M.P., P.R. Richard, R. Dietz, and K. L. Laidre. 2013. A metapopulation model for narwhals. Animal Conservation 16(3): 331-343. doi:10.1111/acv.12000

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